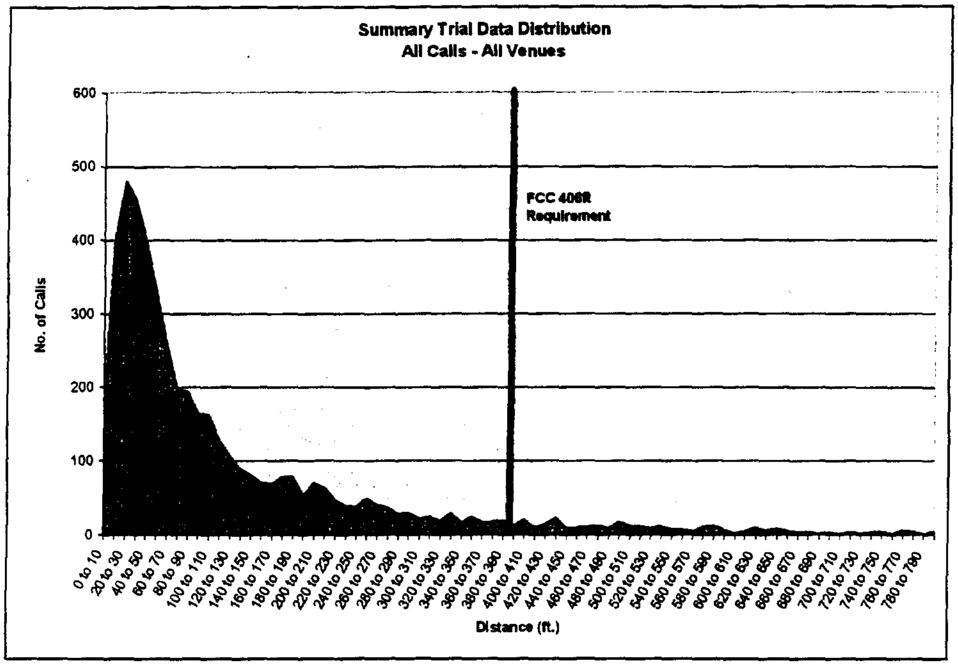
REPORT OF FINDINGS

A Study of Stand-Alone Global Positioning System Determined Location, Cellular Communications, Call Path Signaling and Routing



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PREFACE

The contents of this evaluation are the results of a Technical Evaluation Plan carried out by Integrated Data Communications, Inc. (IDC), located in Bainbridge Island, Washington with the cooperation of the King County, Washington E-911 Program Office located in Seattle, Washington.

Through teaming arrangements with existing wireless carriers, wireline carriers, Public Safety providers and suppliers, IDC was able to document the feasibility of Global Positioning System (GPS)-enabled handsets meeting the Federal Communications Commission (FCC) requirements for wireless location. Also presented are:

- Determinations that GPS-enabled cellular calls could be reliably routed to the most appropriate Public Safety Answering Point (PSAP) based on caller location;
- Caller's location could be displayed on a graphical map or in National Emergency Number Association (NENA) text utilizing existing PSAP equipment;
- That the FCC's 125 meter/67% Root Mean Square (RMS) requirement can be met and exceeded.

The types of equipment used to make the conclusions were chosen for numerous reasons, including: cost, speed of acquisition, availability of parts, engineering time, manufacturing and assembly times, and compatibility with equipment supplied by team members.

Findings are based on actual field test results from the period June 1, 1998 through November 30, 1998. The results are achieved through the state-of-the-art technologies available at the time of the test. IDC made a thorough attempt to secure accurate information in this highly focused, six-month time frame. With 4,870 controlled wireless calls made from all types of environments, air interfaces, and product types, the data supports a conclusion that GPS in the handset, used in conjunction with inband signaling, is a viable solution for the FCC Phase II wireless enhanced 911 service.

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LIST OF ACRONYMS

ACLD:	Automated Call Location Database
AIP:	Air Interface Protocol
ALI:	Automatic Location Identification
AMPS:	Advanced Mobile Phone Service
ANI:	Automatic Number Identification
ANSI:	American National Standards Institute
AOA:	Angle of Arrival
ASCII:	American Standard Code for Information Interchange
ASQC:	American Society of Quality Control
CAD:	Computer-Aided Design
CAMA:	Central Automatic Message Accounting
CDMA:	Code Division Multiple Access
CPE:	Customer Premise Equipment
CTIA:	Cellular Telecommunications Industry Association
DCCP:	Dynamic Client Configuration Protocol
DCP:	Data Control Protocol
DGPS:	Differential Global Positioning System
DSP:	Digital Signal Processor
DTMF:	Dual Tone Multi-Frequency
E-911:	Enhanced 911
FCC:	Federal Communications Commission
FGD:	Feature Group D
GPS:	Global Positioning System
GSM:	Global System for Mobile Communications
IDC:	Integrated Data Communications
iDEN:	Integration Digital/Dispatch Enhanced Network
ISO:	International Organization for Standardization

(List of Acronyms - Continued)

KCS:	King County Sheriff
LEC:	Local Exchange Carrier
MIN:	Mobile Identification Number
MPH:	Miles Per Hour
MSC:	Media Stimulated Calling
N-AMPS	Narrowband – Advanced Mobile Phone Service
NENA:	National Emergency Number Association
OSI:	Open Systems Interconnect
PALI:	Pseudo Automatic Location Information
PANI:	Pseudo Automatic Number Identification
PCS:	Personal Communications Services
PPS:	Precise Positioning Service
PSAP:	Public Safety Answering Point
PSTN:	Public Switched Telephone Network
RF:	Radio Frequency
RMS:	Root Mean Square
RTK:	Real Time Kinematic
SA:	Selective Availability
SPD:	Seattle Police Department
TCP/IP:	Transport Control Protocol/Internet Protocol
TDMA:	Time Division Multiple Access
TDOA:	Time Difference of Arrival
UPS:	Uninterrupted Power Supply
W-ALI:	Wireless - Automatic Location Information
WSP:	Washington State Patrol

1.0 EXECUTIVE SUMMARY

This Field Trial and Study was conducted in cooperation with King County, Washington's E-911 Program Office, existing wireless and wireline Carriers, Public Safety equipment suppliers, and Public Safety service providers[1]. From this cooperative effort, Integrated Data Communications, Inc. (IDC) was able to successfully develop, deploy, test and document a system reference model for utilizing Global Positioning System (GPS) technology to obtain wireless phone location. This trial was performed in the field throughout the Seattle metropolitan area - not in a laboratory environment. The field trial's findings are based on actual and repeatable test results. The trial was conducted between June 1, 1998 and November 30, 1998.

The global questions driving the King County, Washington field trial were:

- Can a handset-based, location-determining technology meet the requirements of the Federal Communications Commission (FCC) Phase II mandate <u>and</u> the needs of Public Safety providers?
- Are the requirements as set forth by the FCC Phase II mandate reasonable and technically achievable?
- Can this solution meet the FCC Phase II (October, 2001) time requirements as published?
- Can this solution address location issues for the embedded base of wireless phones?
- Can the solution roam with the caller?
- Can the mandate be satisfied within current or expected cost recovery bounds?
- Is the technology accurate enough to selectively route wireless 911 calls to the appropriate Public Safety Answering Point (PSAP) based upon the location of the caller?

These questions and others are answered in the balance of this Report of Findings.

With these global questions and FCC requirements[2] in mind, Public Safety[3] asked IDC to deploy and test additional functional requirements from the perspective of Public Safety, which included:

- Selectively routing calls based on the latitude and longitude of the caller;
- Ensuring compatibility with all wireless carrier's systems;
- Displaying caller's location graphically, within the legacy Customer Premise Equipment (CPE);
- Locating a caller to within 12.3 Meters (40 feet);
- Providing the caller's latitude, longitude, altitude, speed and direction of travel;
- Dynamically refreshing the Wireless - Automatic Location Information (W-ALI);
- Finding 90% of all callers within the published requirements.

IDC studied alternative system designs and subsequently chose a "stand-alone", handset-based solution. In this model, the wireless carrier (henceforth termed the "carrier") has a passive role in the caller's location because the caller "owns" the active component: a handset enabled with a Global Positioning System (GPS) receiver. Once IDC chose the location technology, the focus shifted to developing a simple and reasonable method of data delivery to the call taker. Before a system architecture could be developed, numerous factors had to be taken into consideration, including:

- FCC requirements;
- Public Safety's needs;
- Feasibility of sending location data in the voice channel[4].

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[1] See Appendix A in the complete document for a listing.

[2] On July 26, 1996, the Federal Communications Commission (FCC) released its Report and Order on Enhanced 911 Emergency Calling Systems (Docket No. 96-264) which detailed guidelines for a two-phased implementation of wireless E911. Phase I states, "By April 1, 1998, a wireless carrier must be able to locate a 911 wireless call by the cell sector where the wireless call originates." Phase II states, "By October 1, 2001, a wireless carrier must be able to locate a 911 wireless call to within 125 meters, 67% of the time."

[3] IDC staff asked King County E-911 Program Manager Marlys Davis and other PSAP Managers from King County what additional requirements they would like to see included in this Study.

- Feasibility of changing the carrier's infrastructure, considering costs and cost-recovery;
- Carrier concerns regarding reduced system capacity[5].

Since only two paths are available[6], only two methods of data transfer can be employed: call path signaling (inband) or non-call path signaling (out of band). Understanding these two distinct models, a handset solution was developed and centralized within the Local Exchange Carrier (LEC). The LEC was chosen for two fundamental reasons: it is the communications common denominator to all carriers; and it has a history of providing the facilities and technical resources needed to solve and deploy solutions for Public Safety.

In this system architecture, IDC's solution treated the carrier as an extension of the LEC's landline network and further made the handset appear as part of the Public Switched Telephone Network (PSTN). Additionally, the solution was required to be carrier independent and air interface independent[7]. Most importantly, the handset had to be viewed as an extension of the existing call taker's station, and as an extension of LEC's Central Office in Seattle, Washington. When a call is placed and a voice path established, location data must be available to the call taker. At the conclusion of the trial, IDC proved this model to be a low cost, reliable, and reasonably achievable solution.

Furthermore, this model better lends itself to commercialization of location-based applications, with a potential of underwriting some of the costs for Public Safety. This issue is not discussed in this Study as it is beyond the intended scope of this effort.

IDC demonstrated that answers to the primary questions driving this field trial are as follows:

- A handset-based solution meets and exceeds the requirements of both the FCC and Public Safety; across a variety of calling environments (e.g. urban, suburban, mountainous, rural, and waterborne)
- The requirements are reasonable and technically achievable;
- A churn-based transition strategy[8] could achieve implementation in excess of 70% of the installed handset base by October, 2001, assuming a 24% churn (source – Cellular Telecommunications Industry Association), a given beginning unit count, and given subscriber growth count. This churn-based transition strategy is a viable option for the wireless carriers since the publication of Public Notice 98-2631 on 12/24/98[9].
- A retrofit solution (e.g. battery retrofit) can also be part of the strategy to satisfy the embedded base per the FCC Public Notice 98-2631;
- Finally, a unique solution has been objectively tested and documented that demonstrates this mandate can be met within cost recovery bounds.

Accurate and reliable location is important to both Public Safety and commercial applications. This field trial demonstrated, through validation of a reference model, that a handset-based approach can be an accurate, low-cost and deployable solution. Public Safety needs initially drove the FCC requirements, and IDC has proven that this solution can not only meet the mandates of 2001, but can achieve Public Safety's future goals of accuracy and timeliness.

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[4] CAMA, Enhanced CAMA or "Feature Group D"

[5] Industry sources have indicated that congestion in the control channel is causing a reduction in voice capacity, resulting in reduced revenues. In a cost recovery model, secondary build out costs may be hard to justify and collect for.

[6] Cellular and PCS telephones communicate on two channels: an overhead or "non-call path" channel and a voice or "call path" channel.

[7] Protocols are the air interface languages cellular phones use to communicate. There are six employed here in the U.S., they are: CDMA, TDMA, AMPS, GSM, N-AMPS and iDEN.

[8] Industry sources indicate that between 2% - 4% of the customer base are lost to the Carrier on a monthly basis.

[9] Reference "WIRELESS TELECOMMUNICATIONS BUREAU OUTLINES GUIDELINES FOR WIRELESS E911 RULE WAIVERS FOR HANDSET-BASED APPROACHES TO PHASE II AUTOMATIC LOCATION IDENTIFICATION REQUIREMENTS" dated December 24th, 1998. "

The King County field trial was conducted between June 1st, 1998 and November 30th, 1998 throughout the Seattle metropolitan area. Calling locations included:

- Downtown Seattle, WA (urban canyons)
- Mercer Island, WA (suburban and waterborne)
- North Bend, WA (rural)
- Snoqualmie Pass, WA (mountainous)
- Seattle Arboretum (densely forested)
- Washington State Department of Transportation monuments (various roads)

The trial obtained the following results for a total of 4,870 documented calls:

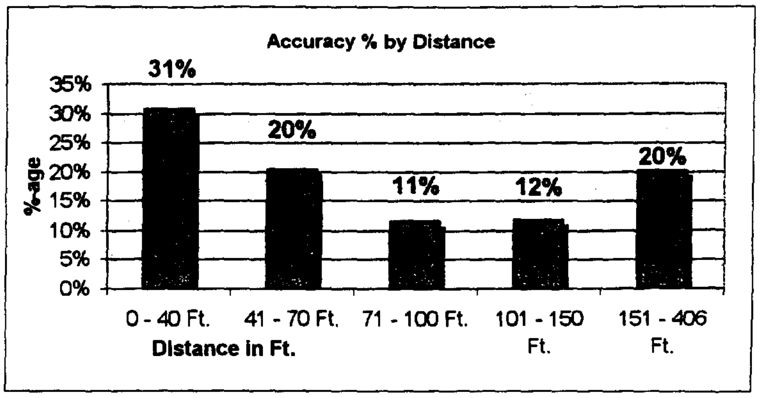
- **31%** of all of the documented calls fell within the 40-ft. accuracy requirement.
- **51%,** or the majority of all calls, were located to within 70-ft.; 20% of the calls were between 41-ft. to 70-ft of accuracy.
- **62%** of all calls fell within 100-ft. of accuracy; 11% were between 71-ft. to 100-ft.
- **74%** of all calls fell within 150-ft. of accuracy; 12% were between 101-ft. to 150-ft.
- **94%** of all scientifically documented calls fell within 406-ft (FCC Phase II requirement) of accuracy; 32% of the calls were between 101-ft. to 406-ft. of accuracy.
- **100%** of all calls were located.

These calls were made using 10 different handset unit models, and with four distinct wireless air interfaces. **Figure 1-1** on the following page provides a graphical summary of our results.

During the course of the trial, IDC worked closely with a variety of technology vendors to obtain its results. In the area of GPS technology, there have been significant advances over the last 6 months in miniaturization, power consumption, and network assistance. Specifically, the GPS engine selected by IDC to obtain the location coordinates in the trial (by SiRF Technology) has made considerable advancements in these areas. The most recent SiRF Technology GRF1/LX RF integrated circuits and GSP1/LX digital signal processing chips collectively include improvements to signal acquisition (Snaplock™), power consumption (TricklePower™), and penetration of foliage (FoliageLock™). Collaborative work between SiRF Technology and IDC is also underway which has demonstrated a breakthrough network-assist mechanism to further improve coverage in buildings, tunnels, and other structures. Other advancements in "cold" and "warm" signal acquisition are also being made by SiRF Technology and throughout the GPS industry. IDC is also working with numerous handset, selective router, and call taker manufacturers to embed its technology into the existing hardware.

The cumulative result of these continued advancements since the conclusion of the trial will be to obtain more accurate readings in all environments (including in-building), quicker "cold" starts, and reduced response times for Public Safety.

Calling Venue	# of Calls
Mercer Island- Suburban	1,533
Snoqualmie Pass - Rural/Mnts.	161
Downtown Seattle - Urban	1,073
North Bend - Rural	1,136
Arboretum - Heavy Forest	452
DOT Monuments - Various	515
Total Calls	4,870



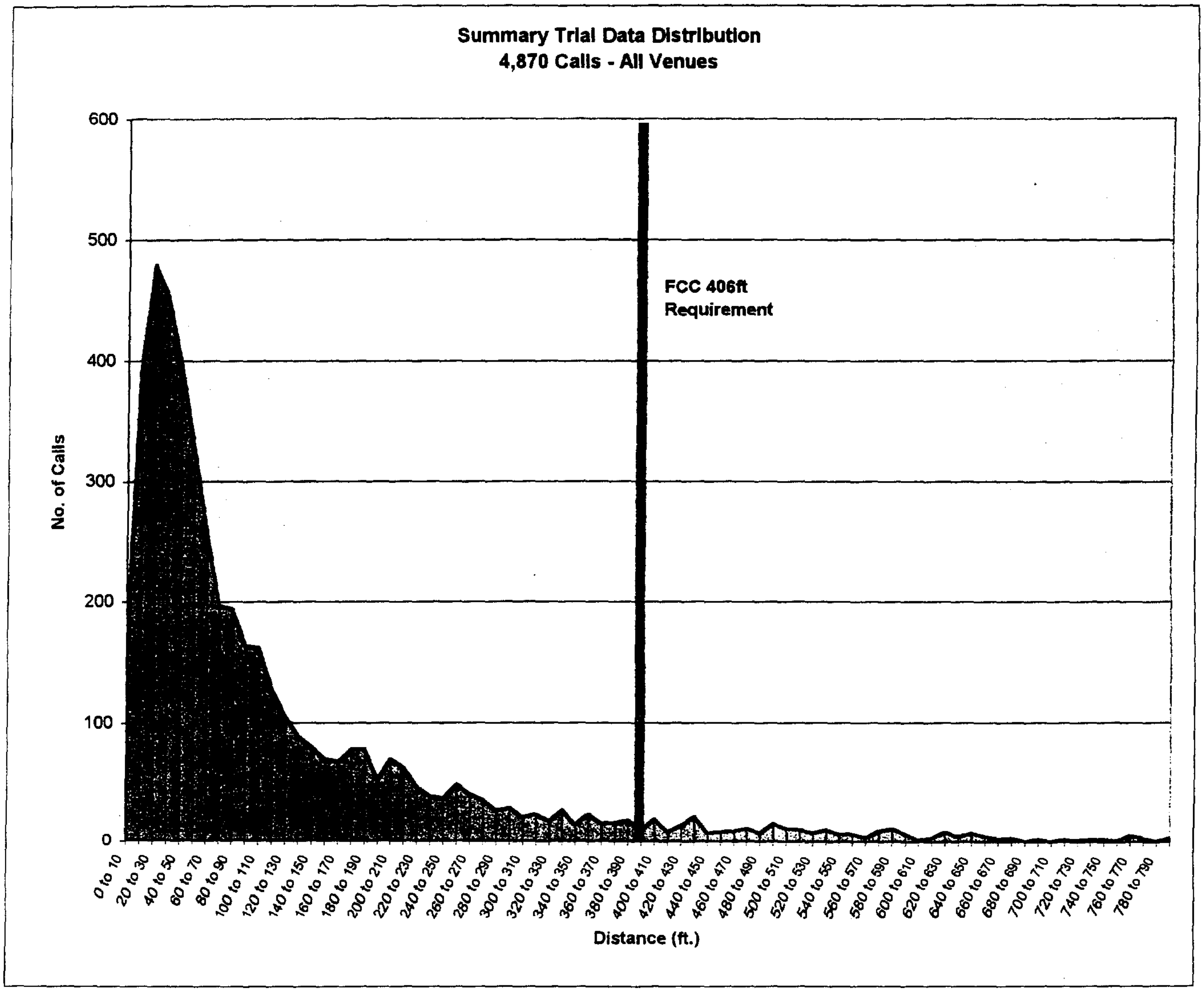


Figure 1-1. Calling Venue Breakdown, Incremental Accuracy by Distance, and Summary Call Distribution

2.0 QUALITY MANAGEMENT SYSTEM

2.1 QUALITY SYSTEM REQUIREMENTS

The Quality Management System is founded on the requirements of the ANSI/ASQC Q9001-1994 standard, and is fully consistent with ISO 9000-9004 organization plan and model.

2.2 QUALITY POLICY

The President and the Certified Quality Board have directed all employees to conduct their work processes guided by the company's quality and environmental policy statement:

"Integrated Data Communications Inc., will ensure that performance satisfies customer needs the first time by planning and verifying work practices while continually improving quality"

Each IDC employee is required to review, sign, and adhere to a statement and policy regarding ISO standards. This documentation is available from the IDC Quality Manager, Mr. Tom Dowler.

3.0 BACKGROUND

3.1 E-911 AND THE NETWORKS

3.1.1 Wireline Networks

Today, when a wireline caller dials 911, the network has the ability to provide Automatic Number Identification (ANI) to the Public Safety Answering Point (PSAP). In a matter of milliseconds, the signal is sent from the LEC's Central Office to the Automatic Location Identification (ALI) database where the name and address of the caller's location is queued up.

The data package completes the final leg of its journey to the PSAP when the ALI controller requests the data. When the PSAP call taker picks up the call, the ANI/ALI information is automatically spilled onto their screen, and they are able to confirm the address with the caller. Unfortunately, the case is not so simple with wireless calls.

3.1.2 Wireless Networks

The nation's first cellular system was introduced in the early 1980's. Today, there are over 69 million wireless subscribers *(source – CTIA)* - a large segment of the U.S. population. This figure is estimated to reach 110 million by 2001. With so many people using wireless phones, emergency calls from wireless callers to 911 have increased dramatically. In 1998, the number of wireless calls per day to 911 totaled over 85,000[1] nationwide. *Most notably, The National Emergency Number Association (NENA) estimates that within five years, the number of wireless 911 calls will exceed the number of landline 911 calls; and that within 10 years, over 70% of the 911 calls would originate from a wireless source.* Wireless telephones are increasingly being used as essential tools in the effort to ensure the broader community's safety, not just for individuals concerned about being able to communicate in emergencies.

The Carrier did not have to deal with the 911 problem when the markets were small because Public Safety was able to handle the calls. ANI was not even available for wireless calls until recently. With explosive growth as well as the dynamic aspects of mobile callers, conventional ALI becomes useless unless the caller is making the call from the billing address. In 1994, the Federal Communications Commission (FCC) decided to act on the problem.

3.2 FCC WIRELESS E-911 REPORT

In 1994 the FCC published a Notice of Proposed Rule Making addressing the issue and set forth the guidelines for a solution. On July 26, 1996, the FCC released its Report and Order on Enhanced 911 Emergency Calling Systems[2], which included guidelines for a two-phased implementation of wireless E-911 ALI. Phase I states, "By April 1, 1998, a wireless carrier must be able to locate a 911 wireless call by the cell sector where the wireless call originates." Phase II states, "By October 1, 2001, a wireless carrier must be able to locate a 911 wireless call to within 125 meters (406 feet) for 67% of all calls."

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1 Estimates provided by the Cellular Telecommunications Industry Association (CTIA)

2 FCC Report and Order and Notice of Proposed Rulemaking, 11 FCC RCD 18676 (1996)

3.3 PUBLIC SAFETY

PSAPs do not currently receive location information with wireless calls. About 40% of wireless callers are unable to relay their location to E-911 call takers. An inability to communicate location was the case for about 34,000 calls per day in 1998. The problem may not change until 2001, unless proactive steps are taken today by Public Safety organizations. Until then, the call taker's only option is to be patient and spend the valuable time necessary to determine the correct location, even if it takes 2.5 to 3 times longer[3] for wireless calls.

3.4 TECHNICAL OPTIONS

Wireless carriers have several location technology options. One approach being tested is tower or network-based; this technique uses either a cell tower triangulation method or antenna arrays to determine time difference of arrival (TDOA) and angle of arrival (AOA) from cell site(s) to the mobile caller. In highly controlled tests over predominantly densely-sited areas or corridors, these methods have proven some measure of success in locating callers within the FCC's guidelines. The network-based solution, however, remains highly problematic. The triangulation method requires exactly what it implies: a minimum of two sites or sectors (for AOA), or three sites or sectors (for TDOA), to achieve a location. The reality in today's wireless buildouts is that two or three towers are not always available, or adjacent to each other at such a distance or angle, to determine a position. This is true especially in rural or sparsely populated areas where often a single site provides service to a town, valley, or other remote area. Furthermore, effects such as deflection and scattering of terrestrial RF signaling make highly accurate location determination (e.g. under 40 feet) difficult and perhaps unachievable.

A second method is handset-based <u>and</u> network-assisted. This solution requires processing support by the Carrier and utilization of the control (out-of-band) channel. This technology will not allow a caller from one Carrier to "roam" on to another Carrier's network and still provide location. This is especially problematic when roaming in 2 distinct ways: 1) "roaming" on an analog channel outside of the digital signal footprint (in the case of dual-mode phones), and 2) for "roaming" outside of the local calling area. These kinds of roaming are increasingly prevalent with the growing use of multi-band and multi-mode phones for such national wireless carriers as AT&T Wireless Services and Southwestern Bell Communications. The flexibility provided with roaming (as customers now expect with this service) must be considered as part of the final solution, regardless of the location technology employed. This technology, as with network-based, has been tested and can be viable with reported capabilities similar to stand-alone Global Positioning System (GPS).

A third method, and the one employed in this trial, is a stand-alone GPS connected to a handset with location data transferred in the call path. By placing the 911 call and establishing a circuit-switched voice path, data is available immediately to the call taker at the other end of the call. One of the keys to this success lies in the development and maturity of highly intelligent and miniaturized GPS receivers to obtain the location information.

[3] Based upon a 1996 study in King County, Washington

3.5 GPS OVERVIEW

The GPS consists of 24 satellites that orbit the earth twice a day at an elevation of about 11,000 miles above the earth. These satellites transmit precise time and position information needed to produce latitude, longitude and altitude, anywhere on Earth 24-hours a day.

Development of the $10 billion GPS satellite system began in the 1970s by the U.S. Department of Defense, which continues to manage the system. GPS provides continuous, worldwide positioning and navigation to U.S. military forces around the world, but also serves broader civilian and commercial applications. To meet these needs, GPS offers two levels of service - one for civilian access, and the second for encrypted military use. The GPS signals are available free-of-charge to an unlimited number of users.

The basis of GPS technology is precise time and position information. Using atomic clocks (accurate to within one second every 70,000 years) and location data, each satellite continuously broadcasts the time and its position. A GPS receiver receives these signals, listening to three or more satellites at once, and determines the user's position on earth.

By measuring the time interval between the transmission and the reception of a satellite signal, the GPS receiver calculates the distance between the user and each satellite. Using the distance measurements of at least three satellites in an algorithm computation, the GPS receiver arrives at an accurate position fix.

Each satellite continuously broadcasts two signals, L1 and L2. The L1 frequency contains the C/A code that provides GPS for worldwide civilian use. The encrypted P-code is broadcast on both L1 and L2 frequency, resulting in the Precise Positioning Service (PPS) for military use. The GPS signal will provide a civilian user accuracy of better than 25 meters (75 feet). Because they are so accurate, civilian GPS receivers using the GPS signal are sometimes subject to Selective Availability (SA). When engaged, SA inserts random errors in the data transmitted from the satellites, and as a result, GPS signal accuracy can be reduced to 100 meters (300 feet).

Using correction techniques such as Real Time Kinematic (RTK) or differential GPS (DGPS), the user can overcome the effect of SA interference and increase the overall accuracy of the GPS receiver. The resulting real-time accuracy is in the 15-meter (45-foot) range. Sub-meter accuracy can be obtained by using DGPS and post-processing calculations in static positioning. Effective in mid-1998, the L2 channel became available to commercial applications. This will yield sub-meter accuracy when employing DGPS.

4.0 TECHNICAL INPUTS FUNCTIONAL REQUIREMENTS

4.1 FEDERAL COMMUNICATIONS COMMISSION (FCC) REQUIREMENTS

The FCC requirement is contained in the Report and Order section of the FCC's Executive Summary of Commission Actions from docket No. 96-264, released July 26, 1996. The Phase II requirement of this document states that "By October 1, 2001, a wireless carrier must be able to locate a 911 wireless call to within 125 meters (406ft.) for 67% of all calls". More detailed information regarding this Report and Order is provided within Appendix H of this document.

4.2 KING COUNTY, WA REQUIREMENTS - GENERAL

King County in Washington State covers about 2,200 square miles, and includes the City of Seattle. The county has a population of over 1.6 million people. In 1997, there were 1.8 million calls to the 18 separate Public Safety Answering Points (PSAPs) located in King County. Approximately 300,000 of those calls were from wireless customers of five different wireless carriers. The calls are routed to one of five regional PSAPs by cell site/sector per the Phase I FCC wireless location requirements. **Figure 4-1** is a map of the King County, Washington area.

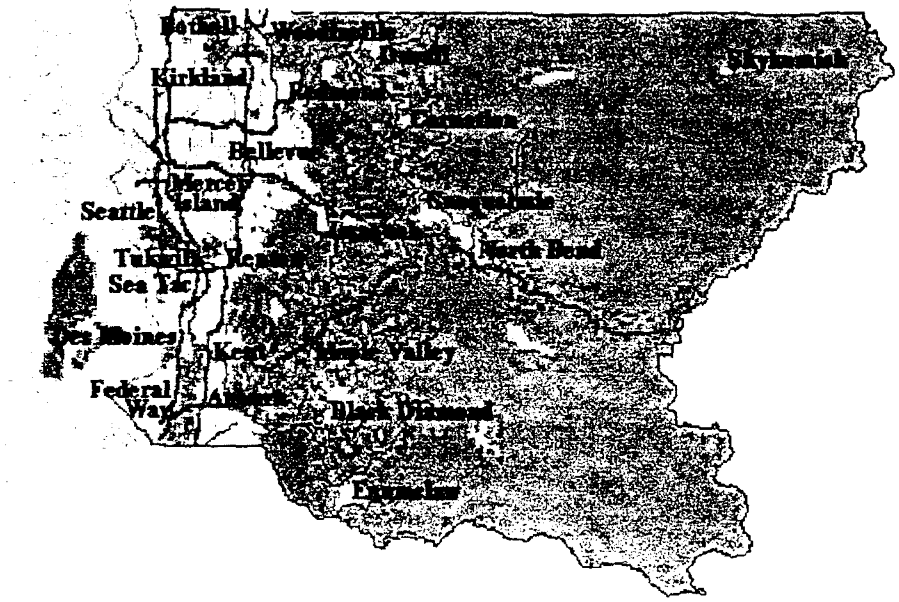

Figure 4-1. Map of King County, Washington

4.3 KING COUNTY, WA - PSAP USER FUNCTIONAL REQUIREMENTS

4.3.1 Latitude, Longitude

4.3.1.1 Accuracy within 40 feet.
4.3.1.2 90% of the test 911 calls.

4.3.2 Altitude

4.3.2.1 Altitude reference is ground level, not sea level.
4.3.2.2 For buildings, altitude expressed in feet and floor # if possible.

4.3.3 Speed

4.3.3.1 In miles per hour.

4.3.4 Direction Of Travel

4.3.4.1 In '8-point' directionals (N, NE, E, SE, S, SW,W, NW).

4.3.5 Customer Information To Be Provided

4.3.5.1 Customer name.
4.3.5.2 Customer billing address.
4.3.5.3 Calling party number.

4.3.6 Information Display

4.3.6.1 Information is to be displayed on existing Positron Lifeline™ ANI/ALI display.
4.3.6.2 Information is to be displayed as a separate display on a map, as well as textually.
4.3.6.3 Information to be updated every 15 seconds on demand, controlled by call taker.
4.3.6.4 Updated information is not to displace original call information.
4.3.6.5 Average time for display of information is not to exceed two (2) seconds until first character is displayed on the ALI screen/separate mapping display screen.

4.3.7 911 Call And Information Routing

4.3.7.1 Test calls are to route based on latitude/longitude of original call (selective routing).
4.3.7.2 Voice and data are to route based on existing E-911 network, through existing E-911 controller and telephone equipment.

4.3.8 Areas From Which Test Calls Are To Be Placed

4.3.8.1 Mountainous areas
4.3.8.2 Skyscrapers and urban canyons
4.3.8.3 Tunnels
4.3.8.4 Highways serviced by: Seattle Police Department, Washington State Patrol and the King County Sheriff's Office.
4.3.8.5 General neighborhoods
4.3.8.6 Waterways

4.3.9 PSAPs To Be Included In Test (total of 3)

4.3.9.1 King County Sheriff PSAP (downtown Seattle)
4.3.9.2 Seattle Police Department PSAP (downtown Seattle)
4.3.9.3 Washington State Patrol (Eastgate, 156th Street)

4.4 KING COUNTY REQUIREMENTS VS. FCC REQUIREMENTS

The King County requirements stated in paragraph 4.3 are more stringent than the FCC requirements. While the FCC requires the location to be accurate within 125 meters (406 feet) for 67% of the calls, King County requested accuracy to 40 feet (12.3 meters), 90% of the time. *It is the consensus of the PSAPs in King County, WA that approximately 40 feet is the level of accuracy needed for the location to be usable for effectively dispatching assistance to the caller.* **Figure 4-2** (below) compares these requirements – using both radiuses from the actual location (406-ft. meters vs. 40-ft. meters) and the area of the location (517,847 square feet vs. 5,025 square feet). Based upon the accuracy of the area, the King County, WA requirements are 103 times more accurate than the FCC Phase II requirement.

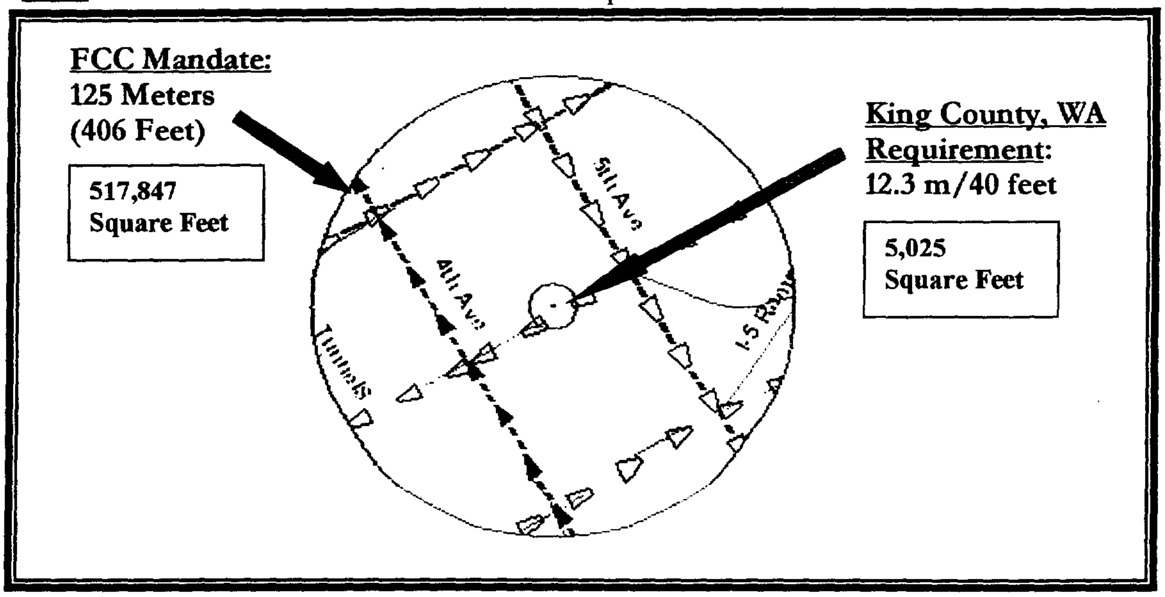

Figure 4-2. Comparative radius and area accuracies – FCC requirements vs. King County, WA Requirements

5.0 TECHNICAL APPROACH THEORY/SOLUTION

5.1 APPROACH

IDC studied alternative system designs and subsequently chose a "stand-alone" Global Positioning System (GPS) solution. In this approach, the Carrier has a "passive" role in the caller's location (in that location information is passed through the network, with no modification to the network), and the caller "owns" the active component: a handset with a GPS receiver. This solution would <u>not</u>, however, preclude the landline carrier, the wireless carrier or other vendors or integrators from developing and implementing location-based applications using GPS technology.

For the handset-based, GPS engine approach to obtaining location information, there are two methods, or system reference models, that can be employed:

- Call path signaling (inband)
- Non-call path signaling (out of band)

Cellular, Personal Communications Services (PCS), and other wireless phones basically communicate on two channels: an overhead or "control" channel and a voice or "traffic" channel (i.e. the call path). To mitigate cost and capacity issues as a result of congestion of the control channel, IDC chose to send location data in the call path, much like is done throughout E-911[1]. This approach put the intelligence in the handset of the mobile caller, and intelligence in the call taker's station. When an E-911 call is placed and a voice path is established, data is virtually immediately available to the call taker. Accordingly, deployment can be facilitated universally, without dependence upon specialized transport[2] with advanced signaling capability. This is a huge advantage to areas – mostly rural – where Public Safety Answering Points (PSAPs) do not have the latest signaling technology available. **Figure 5-1** depicts this call path solution.

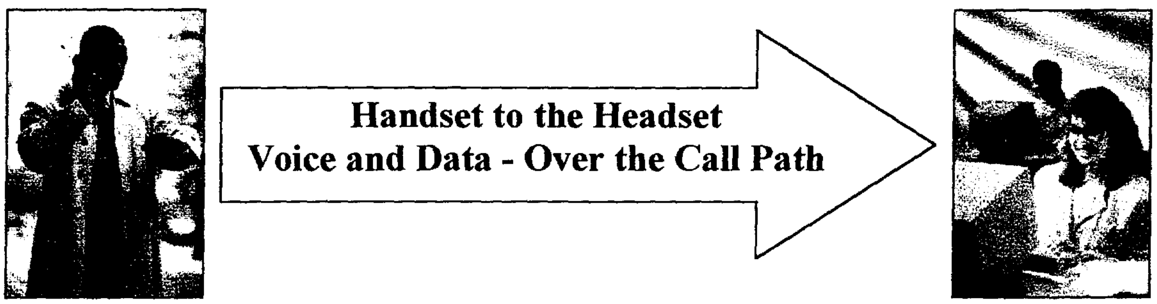

Figure 5-1. Handset to Headset Call Path Solution

5.2 SELECTING THE "BEST IN CLASS" GPS

Because GPS technology is evolving and has not yet reached its theoretical limits, IDC decided to conduct an independent evaluation of the top five GPS receivers. The initial evaluation began in October of 1997. At the conclusion of the evaluation, SiRF Technology,

[1] CAMA, Enhanced CAMA or "Feature Group D"
[2] e.g. Signaling System 7

Inc. of Santa Clara, California, was identified as "Best In Class" receiver with respect to acquisition times, signal availability, power consumption, size, and projected cost. In addition to the objective results obtained in this evaluation, it was our belief that SiRF Technology was developing their receiver technology faster then the rest of the industry. During the study, IDC deployed and tested three different SiRF Technology-based receivers. With each new version of SiRF GPS chipsets came increased accuracy and faster GPS signal acquisition times. It is important to remember that these tests were done in "real world" wireless calling environments, such as urban canyons, mountains, and even waterways. IDC believed that the test had to reflect the "real world" 911 calling patterns of today's PSAPs in order to obtain useful results.

5.3 THEORY

IDC's approach to this solution was developed in accordance with the Open Systems Interconnect (OSI) reference model. OSI is a standard reference model for communication architecture and protocol between two end-applications through a network. The OSI reference model describes seven layers of related functions that are needed to send data from one application to another in a network. It is also the standard reference model used in developing communications products and standards.

The OSI model describes the flow of data in a network from the lowest layer (physical) up to the layer containing the user applications, by passing data from layer to layer. **Figure 5-2** below depicts the OSI model overlaid with the IDC model:

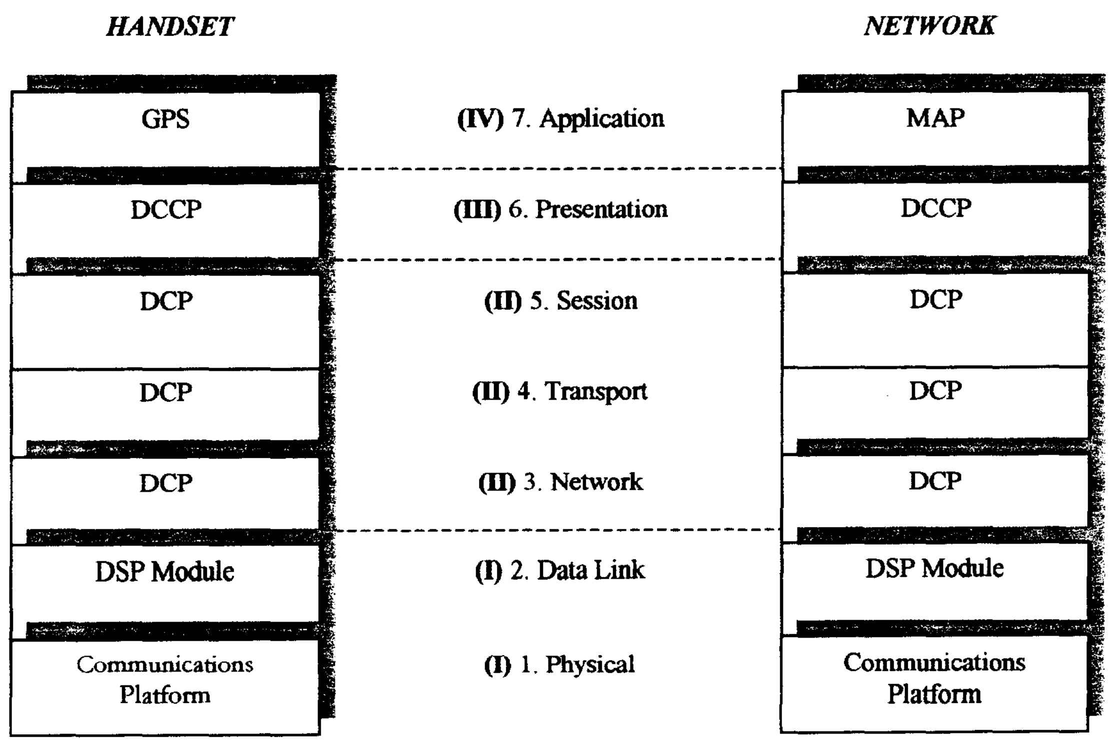

Figure 5-2. ISO Model and IDC Implementation of the Model

Although mention of the OSI model is typically mandatory in the design process, it is also useful as a base of comparison to the IDC model. Whereas the OSI model came from work done by standards committees, the IDC model came out of practical application and experimentation accomplished by its staff who were building an actual network architecture and deploying the technology into a live environment. The IDC protocol "layers" built on top of the physical layer have proven sufficient for practical purposes, as evidenced by this trial, to reliably and accurately transmit a caller's location to a graphical interface at a call taker's station.

Using the model displayed in Figure 5-1, IDC redefined the OSI object layers into four distinct regions **(I-IV in bold):**

- **Layer I**, the lowest region, contains the physical and data link layers.
- **Layer II** supports the session, transport and network layers and is defined as the Data Control Protocol (DCP)[3] layer.
- **Layer III** is the presentation layer, defined as IDC's Dynamic Client Configuration Protocol (DCCP)[4].
- **Layer IV** consists of the applications that generate and use the location data.

IDC's technology provided the "transport" vehicle required for the calling session, not unlike what the TCP/IP protocol accomplishes for the internet. The IDC protocol allows the transport of GPS information from the handset, across the wireless and wireline networks, and represents the location on a call taker's screen in the form of a mapped position.

5.4 VALIDATION OF THE REFERENCE MODEL

The King County trial was designed to test the system architecture and overall design concept. The strategy was to objectively test and document this reference model. Many questions were answered successfully; most importantly, the reference model was proved viable to gather, transport, and display location information from a GPS-enabled handset to an E-911 call taker's station.

[3] DCP: a proprietary communication protocol developed by IDC to meet the requirements of public safety and commercial call taker applications.

[4] DCCP: a proprietary configuration protocol developed by IDC that supports compression, encryption and unique addressing formats.

6.0 TECHNICAL EVALUATION
THE PLAN AND STUDY

6.1 OVERVIEW OF THE TECHNICAL STUDY

6.1.1 Background

In the search for an accurate location service that required minimal impact to the existing infrastructure, Integrated Data Communications (IDC) and King County conducted a comprehensive handset-based wireless E-911 field trial. IDC supplied the inband communications protocols and integration for a team of participants to implement a "wireless handset to dispatcher headset" location solution, which included selective routing of calls to the appropriate Public Safety jurisdiction. At King County's request, IDC used existing equipment and vendor technology, while adding new participants and products as required to complete implementation of the parts of the model discussed in Section 5.0. IDC's augmentation of Global Positioning System (GPS) receivers and its proprietary Data Control protocols to the handsets was all that was required of the wireless carriers involved in the demonstration.

6.1.2 Test Areas

The King County E911 Program Office determined the test calling areas and required IDC to demonstrate its wireless location system in diverse environments to include; urban canyons, waterfronts, mixed-use suburban areas, and mountainous areas near Snoqualmie pass (east of Seattle on I-90). Weather conditions in Seattle and in the mountain regions included substantial inclement weather throughout the demonstration. **Figure 6-1** includes actual photographs of calling locations used during the field trial; note that calls were made from a variety of challenging venues throughout the greater Seattle, Washington area.

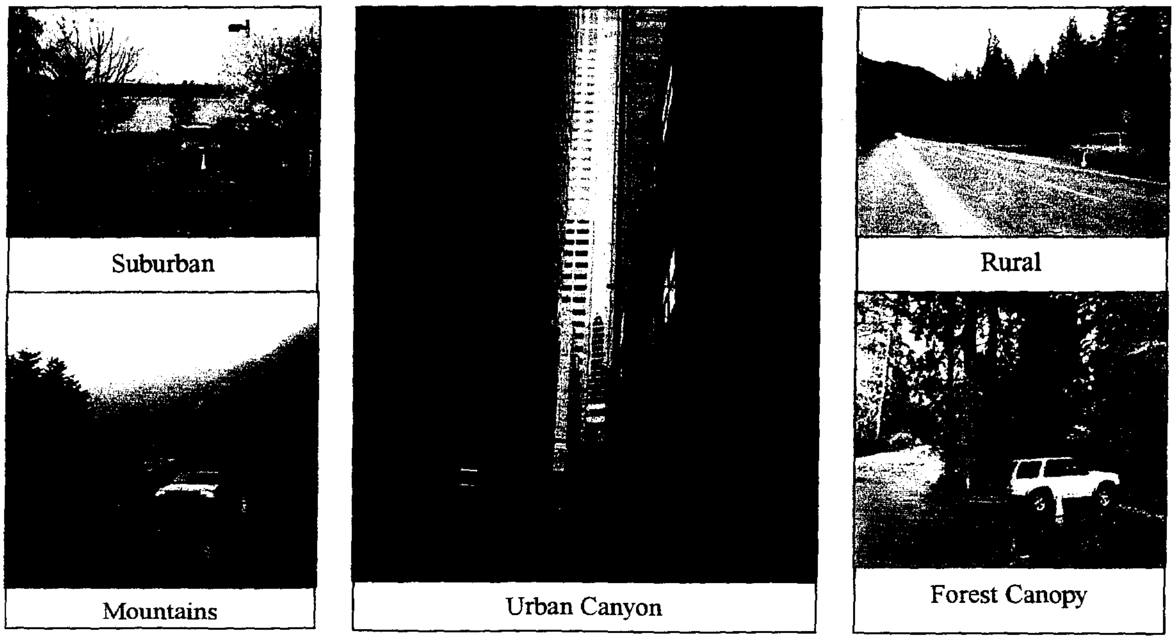

Figure 6-1. Samples of Diverse Calling Environments for the King County Trial

6.1.3 Additional Test Participants and Roles

The Public Safety Answering Point (PSAP) was provided with a call location processor that included a GPS-corrected map for displaying the call, and the caller's location was displayed on the existing call taker's workstation. This map was provided by Network Design Engineering, Inc. The call location processor added a bitmap map to Positron Industries new Power 9-1-1 equipment. WR Inc., another trial participant, re-radiated a building to demonstrate the viability of finding a caller in an area where GPS signals were not normally available. Finally, Network Orange provided equipment to monitor the network during the demonstration to validate communications and time budgets.

Minor modifications to the network infrastructure were performed with the following participants:

- The addition of a protocol converter provided by Proctor & Associates was required by U.S. West (the Local Exchange Carrier or LEC) to extract data and send it to the geographic database for jurisdictional selective routing based on the coordinates.
- The LEC's database, managed by SCC Communications, required minor modifications to route calls based on location.

6.2 GENERAL ASSUMPTIONS

In order for the Study to be successful, IDC listed the assumptions and identify system variables.

6.2.1 Major Wireless Carriers Will Participate

Correct. Most major wireless carriers that have a stake in complying with the Federal Communications Commission (FCC) Phase II requirements were approached. IDC requested they furnish cellular telephones to test through their respective networks and protocols. The responding companies were GTE Wireless, AirTouch, and Nextel. IDC, through personal accounts, used the phones and networks of AT&T Wireless and Sprint PCS to conduct additional, non-official, tests.

6.2.2 All Types Of Communication Protocol Phones Will Be Used In The Trial

Incorrect. IDC tested four different air interface protocols: CDMA, AMPS, N-AMPS, and iDEN. They were unable to test any GSM phones because the GSM network in Seattle (VoiceStream by Western Wireless) was not available for testing or commercial use. The networks and mobile phones of Sprint PCS and AT&T Wireless were not an official part of the trial.

6.2.3 Data Can Be Passed Through All Available Air Interface Protocols

Correct. Of all tested protocols, networks, and switches, data was acquired, sent and received.

6.2.4 GPS Can Be Acquired Wherever Cellular Phones Can Transmit

Incorrect. Some anomalies presented themselves during the trials. Most of these are correctable issues, and those that appeared uncorrectable did not pose problems significant enough to affect the outcome of the trials.

6.2.5 Seattle King County Is A Challenging GPS Acquisition Environment

Correct. King County, Washington is an appropriate location to test GPS location technology. The inner city canyons of Seattle are very deep and narrow, weather is diverse, there are thick forests and high mountains and finally, it borders on a huge body of water known as Puget Sound. The King County area provided a highly differentiated environment representative of the majority of major metropolitan areas throughout the country.

6.2.6 SiRF Technology Chipsets Are The Appropriate GPS Receiver

Correct. IDC looked at different GPS-manufactured sets throughout the trial. They found that no other GPS chipset could acquire and re-acquire data as quickly as SiRF Technology. Understanding that the technology would need to be further developed, SiRF Technology was nonetheless a highly willing and supportive participant and could meet the County's time requirements. Moreover, other manufacturers that used the SiRF Technology chipsets were very helpful in providing insight and product for the trials.

6.2.7 IDC Could Make Use Of US West Labs

Correct. US West was very cooperative and helpful.

6.2.8 System Is Router Protocol Independent

Correct. The data can be routed by latitude/longitude through any manufacturer's router with the attachment of IDC technology.

6.2.9 System Is PSAP Station Protocol Independent

Correct. Positron PSAP call station equipment was used for testing because King County's installed base was Positron equipment. With the attachment of IDC technology, all of IDC's intellectual property in the form of software programs was placed within the existing software/hardware of the call taker station without any modifications to the existing equipment.

6.3 DEFINITIONS, GIVENS, SPECIFIC ASSUMPTIONS AND QUANTIFICATION OF SYSTEM VARIABLES

6.3.1. Mean, μ: an index of central tendency

$$\mu = \frac{\Sigma (x_1 \ldots x_n)}{n}$$

Variance, σ^2: an index of variability used to calculate the dispersion of a given population.

$$\text{Variance} = \sigma^2 = \frac{\Sigma (x_1 \ldots x_n - \mu)^2}{n}$$

Standard Deviation, σ: an index of variability used to characterize dispersion among the measures in a given population.

$$\text{Standard Deviation} = \sigma = \sqrt{Variance}$$

6.3.2. RMS for Location Determining Technology (LDT):

RMS_{LDT} for reported values to actual values less than or equal to 1 km =

$$\sqrt{\frac{\sum_{1}^{(n')}\left[\sqrt{((x_1 - x_1')6080)^2 + (\cos x_1 (y_1 - y_1')6080)^2} \bullet\bullet\bullet \sqrt{((x_{(n')} - x_{(n')}')6080)^2 + (\cos x_{(n')}(y_{(n')} - y_{(n')}')6080)^2}\right]}{(n')}}$$

Where:

- n = The total population
- r = Roaming population and is < n
- n' = (n-r) a modified population
- x_1 = The reported latitude in decimal minutes at call location 1
- y_1 = The reported longitude in decimal minutes at call location 1
- x_1' = The actual latitude in decimal minutes at call location 1
- y_1' = The actual longitude in decimal minutes at call location 1
- $x_{n'}$ = The reported latitude in decimal minutes at call location n'
- $y_{n'}$ = The reported longitude in decimal minutes at call location n'
- $x_{n'}'$ = The actual latitude in decimal minutes at call location n'
- $y_{n'}'$ = The actual longitude in decimal minutes at call location n'
- $\cos x_1$ is the convergence factor for y_1 (longitude) at location 1, x_1 is in decimal degrees
- 6080 is the number of feet in 1 minute of latitude

6.3.3 Specific Technical Assumptions of the Study

- No calling distribution data was available at the time of the trial to determine the most "real world" distribution of calling environments. Information from King County personnel showed that approximately 48% of the E911 calls to the PSAPs were from the major highways. IDC worked closely with King County to determine the mix of calling environments (e.g. urban, suburban, rural, mountainous, waterborne) most reflective of the distribution of callers dialing into the PSAPs.
- Conventional terrestrial cellular only
- RMS methodology is appropriate
- Error calculations utilizing RMS methodology are statically determinate for all populations
- RMS and Standard Deviation are the same
- The RMS algorithm is technology neutral
- All variables are bound to real numbers
- All calls are bound to defined ranges
- All calls are located
- Theoretical range limits (D) for any tower are a function of the wireless devices effective capability (R_{eff}) within the network.
- For roaming callers the mean distance for:
  - multi-face towers are $\pm$ (.5D)(R_{eff}) the distance of the theoretical range limits of the given cell face for an identified call population[1]
  - omni-tower sites are $\pm$ 2(.5D)(R_{eff}) the distance of the theoretical range limits of the wireless device for an identified call population[2]
- $R_{eff} = .6$
- $r = .08n$
- $n' = .92n$
- $\sigma_1 = 67\%$ of (n')
- $\sigma_2 = 95\%$ of (n')
- $\sigma_3 = 99\%$ of (n')
- Convergence error of the n' population at any latitude of < 1 nautical mile is insignificant[3].

6.4 DATA COLLECTION METHODOLOGY

In the quantitative phase, data was collected as part of a systematic data sampling plan in accordance with the Technical Evaluation Plan (Appendix B) and Technical Evaluation Procedures (Appendix C). In the qualitative phase, calls were made randomly throughout the test areas.

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[1] If a multi-faced cell tower in an urban call population has a theoretical range of 1000 Meters, then the bounded distance is defined as .5(1000M)(.6) = ± 300M

[2] If an omni site in an rural call population has a theoretical range of 4000 Meters, then the bounded distance is defined as 2(.5)(4000M)(.6) or ± 2400M

[3] If the latitude between measured and actual at latitude 44° is 1 nautical mile, (1 minute) or less, then convergence error induced will be < 1.24 feet, mean would be .62 feet. (e.g. The distance of 1 minute of longitude at 44° 30 minutes latitude is cos 44.50000*6080 = .71325044*6080 = 4336.56 feet and the distance of 1 minute of longitude at 44° 31 minutes latitude is cos 44.516667*6080 = .71304652*6080 = 4335.32).

6.5 DATA COLLECTION AND DOCUMENTATION

6.5.1 Quantitative Data Collection (Objectively Documented - Controlled)

The data was collected with a utility software package developed by IDC to automatically perform Automated Call Location Database (ACLD) logging. Appendix E contains a sampling of the data sets. Procedures for the ACLD phase are contained in Appendix C. The final results of this phase are presented in Section 7.

6.5.2 Qualitative Data Collection (Subjectively Documented - Anecdotal)

A secondary method was developed to collect the calltakers comments during actual mobile calling. This procedure was used to document a wireless location call; the goal was to document the usefulness of the data. 105 calls were made and documented under this scenario over the course of several days to a live call taker at the PSAP. The findings of this phase are presented in Section 7.

6.6 DATA REDUCTION

6.6.1 Quantitative Methods

Scattergram Analysis Tool

6.6.2 Qualitative Method

Manual evaluation

6.7 ELEMENTS NOT TESTED IN THIS STUDY

The following elements were not tested as part of this field trial as the key objectives and requirements were derived from the Public Safety users:

- Antenna type
- Antenna Placement
- Power consumption
- Battery life
- Effects of Selective Absorption Rates
- Form factor